DIATHERMY

ITS PRODUCTION AND USES IN MEDICINE AND SURGERY

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Diathermy Machines of French Design.

Gaiffe-Gallot et Pilon, of Paris, make a diathermy machine which presents certain distinctive features. It is shown in Fig. 32. The plan is shown in Fig. 33. ABC represents the combined oscillator and resonator. It is made of stiff copper ribbon. The portion from A to B is the oscillator and that from B to C is the resonator. There are two main condensers, D and E. One set of plates of E is connected to the end A of the oscillator. One set of plates of the other condenser D is connected to the other end B of the oscillator. The two terminals which are connected to the patient's electrodes are shown at (1) and (2). One of these is connected to the end A of the oscillator; the other terminal is connected to the end C of the resonator; B is a movable contact. By means of the disc seen on the front of the cabinet (Fig. 32) it can be made to slide along the coil either towards A (Fig. 33) or towards C. If moved towards A the length of the oscillator is diminished and that of the resonator increased. As it approaches A the current in the resonator diminishes, and finally sinks to zero, when B and A are in contact. On the other hand, when B is moved from A towards C the current in the resonator increases. It reaches its maximum when B is near C. Two small condensers, F and G, are inserted in series in the circuit containing the resonator.

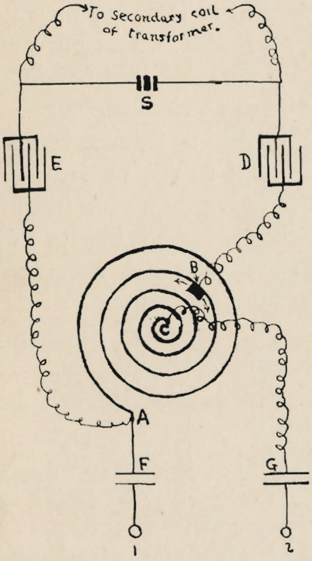

Fig. 33.—Explanatory plan of diathermy machine by Gaiffe-Gallot et Pilon.

The spark-gap is of the type introduced by Broca. It consists of an aluminium cylindrical chamber, the ends of which are closed by mica discs. Attached to the centre of each disc is a thick screw, one end of which is in the interior of the chamber and the other end outside. The inner end carries a copper disc, the outer end a milled-edge button. A third copper disc is fixed in the interior of the chamber. The spaces across which the sparks pass lie between the third disc and those attached to the inner ends of the screws. By turning the latter the width of the spaces can be varied. The air in the interior of the chamber is replaced by coal gas.

Diathermy Machines of American Design.

The diathermy machines made by various firms in the United States of America differ markedly, in some respects, from those designed by European makers. Multiple spark-gaps of the " open " type seem to have been universally adopted. The sparks pass between narrow tungsten discs. In the smaller machines there are three or four pairs of discs. In the larger machines there are six, eight, ten or more pairs. The distance between each pair can be varied as desired or reduced to zero. The discs are mounted on the ends of metal blocks. Metal fins are attached to the latter in order to prevent overheating.

In the larger machines the main condensers are of the Leyden jar type; in the smaller models plate condensers are used.

For the purpose of regulating the current to the patient the method is quite different from that adopted in European machines. In the American machines the regulation is effected both by altering the strength of the current supplied to the machine and by varying the width and number of air spaces in the spark-gap. These methods of regulation are used in conjunction. If the operator desires to administer only a small diathermy current the spark-gap is narrowed; either by reducing the width of all the air spaces or by closing some altogether. At the same time the current taken by the machine is reduced to a small amount. If a stronger diathermy current is desired the incoming current is increased and the spark-gap is widened. The machines give their maximum output when the current supplied to them attains the maximum value for which they are designed and the spark-gap is at its maximum width. If they are widened beyond a certain limit the sparks become very noisy and the patient may feel a " faradic " sensation.

The larger American machines are provided with Oudin or Tesla transformers whereby high-voltage currents are obtained for treatment by the high-frequency effluve and for those forms of surgical treatment known as " fulguration " and " electro-desiccation."

The latest machines are provided, in addition, with thermionic valves so that the so-called " cutting current " used in surgery can be obtained (see *Surgical Diathermy*, p. 244).

Diathermy Machines by H. G. Fischer.

Machines of small, medium and large size are made. By the courtesy of Mr. Fischer the writer was shown the construction and testing of the various models in the workshops and laboratories of the factory at Chicago. The machine illustrated in Fig. 34 is one of medium size. An explanatory plan is shown in Fig. 35. AB represents the primary coil of a static transformer. One of the cables from the main is connected to the end A. The other cable can be connected either to the end B or to any of the intermediate turns of the coil. The main condensers are represented at E and F, and the spark-gap at S. The coil GH represents the oscillator, and HL the resonator. The terminals (0), (1), (2), (3) and (4) are connected to various points of the oscillator and resonator.

The alternating current from the main passes along the primary coil of the transformer, either its entire length or as many turns as desired. By rotating the crank shown at the centre of the panel (Fig. 34) the number of turns included in the main supply circuit can be varied. In this way the voltage to which the current in the secondary coil of the transformer is raised can be regulated, as well as the voltage of the current supplied to the patient. The main condensers are charged from the current induced in the secondary coil. The high-frequency current accompanying their discharge oscillates in the circuit containing the condensers, spark-gap and the coil GH (the oscillator). The current for the patient is taken from the end G of the oscillator by way of the terminal (0), and from another turn of the oscillator or resonator (M, H, K or L) by way of the terminals (1), (2), (3) or (4). If a low voltage current is required, as for diathermic coagulation or for treatment of a region of the body

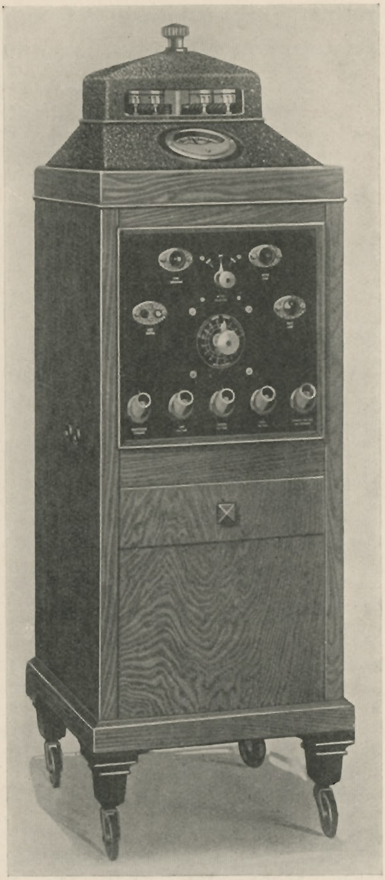

FIG. 34.—Diathermy machine by H. G. Fischer, Chicago. (Smaller and larger models are made. The five terminals from which current is led to the patient (0 to 4, fig. 35) can be seen on the lower end of the panel. The crank at the centre regulates the current taken by the machine. The spark-gap is seen on the top of the cabinet, and the ammeter just below it.

offering low resistance, the cables from the patient are attached to the terminals (0) and (1). These derive a low-voltage current from the end G of the oscillator and from another point (M) a few turns away. The current derived from the terminals (0) and (2) is supplied at a medium voltage; that derived from (0) and (3) is supplied at a high voltage; that derived from (0) and (4) is supplied at a much higher voltage. The points of the oscillator and resonator to which these terminals are connected are fixed. The currents at medium and high voltage are used for treatment of regions of the body that present a medium and high resistance. The current derived from the extreme end L of the resonator is at a voltage high enough to give a brush discharge. When it is employed the patient is not, as a rule, connected to the terminal (0), the application being mono-polar.

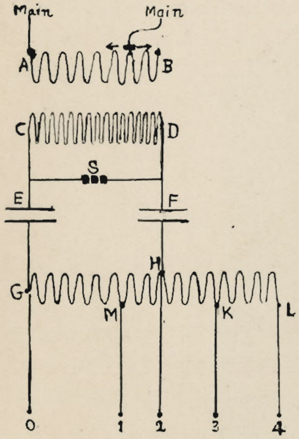

Fig. 35.—Explanatory plan of machine shown in Fig. 34.

When a patient is to be subjected to diathermy the region of the body requiring treatment, whether of low, medium or high resistance, will decide the terminals to which the electrodes are connected. If the current is to be directed from hand to hand, or from foot to foot, the resistance will be high, and the electrodes should be connected to (0) and (3). If a single joint is to be treated the electrodes should be placed on opposite aspects and connected to (0) and (1). If a region of the trunk is to be treated the electrodes may be connected to (0) and (2). The strength of the current is regulated (1) by varying the number of turns of the primary coil of the transformer traversed by the main supply current, and (2) by varying the width of the spark-gap. The former gives even regulation within narrow limits, and the latter gives *abrupt* regulation in steps, but within broad limits.

In actual practice the procedure is as follows. After connecting the patient to the correct terminals, as stated above, the crank shown in the centre of the panel (Fig. 34) is placed with its pointer at I.

The spark-gap is closed. This is effected by rotating the ebonite handle shown in Fig. 34 on the summit of the cabinet. The supply current is switched on. The spark-gap is opened and gradually widened to the maximum. If the amperemeter does not indicate the desired current for the patient the current from the main is switched off, the spark-gap closed and the crank turned to (2). The main current is now switched on again and the spark-gap opened and its width increased. This process is repeated until the desired current is obtained for the patient.

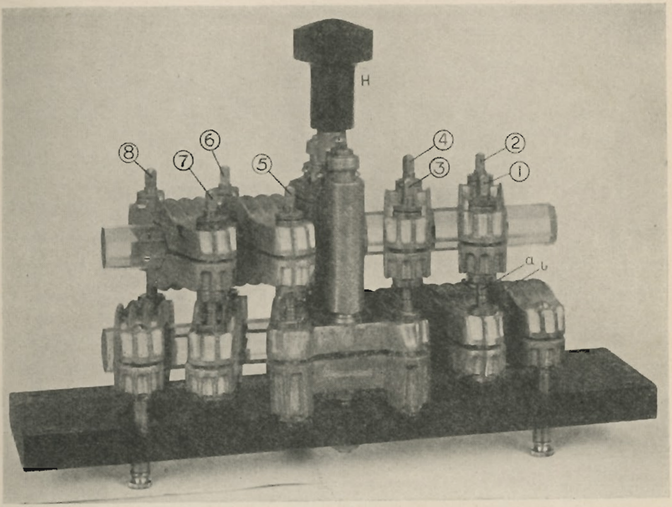

Fig. 36.—Spark-gap fitted to diathermy machine by H. G. Fischer. There are eight separate gaps. *a* and *b* are the tungsten-tipped discs bounding one of the gaps. By turning the master-key H the eight gaps can be closed, or their width varied, simultaneously. By turning any one of the ends (1) to (8) the width of the corresponding gap can be varied apart from the others.

After practice the operator will be able to set the crank approximately at the correct figure before commencing to treat different regions. He can then increase the current to the desired value by adjusting the width of the spark-gap.

The spark-gap is of the multiple type. There are eight separate gaps in series. Each is formed between tungsten discs. By rotating the handle shown in Fig. 34 on the top of the cabinet the width of each gap can be varied simultaneously; all the gaps can be closed and all can be opened to the same width. On the other hand, one gap alone, or two or more, can be opened and the others left closed. The

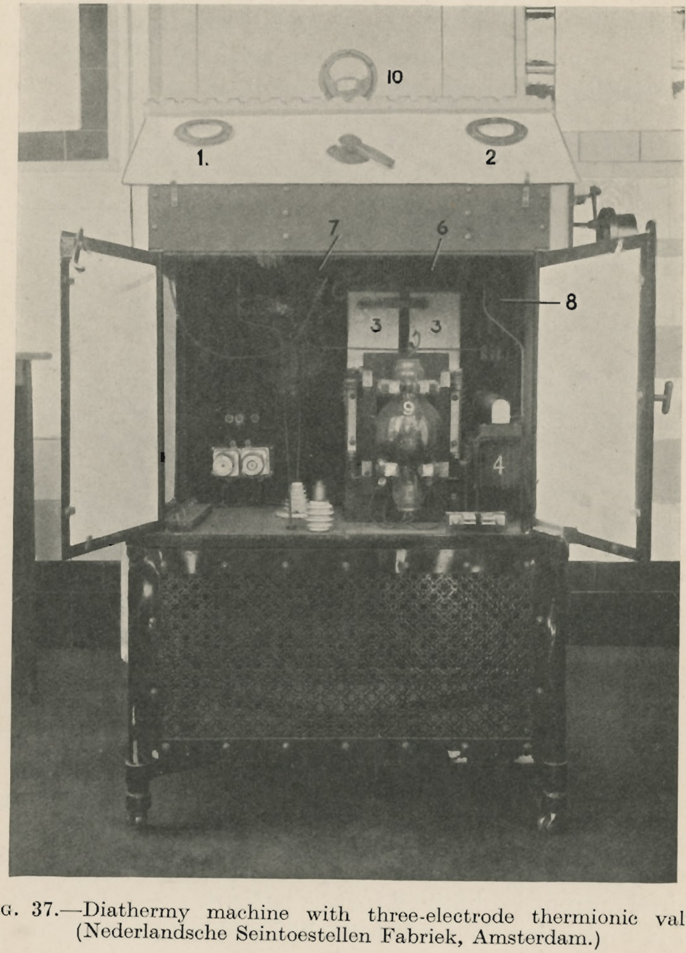

Fig. 37.—Diathermy machine with three-electrode thermionic valve. (Nederlandsche Seintoestellen Fabriek, Amsterdam.)

first procedure is generally adopted. The closure of all the gaps save one and the regulation of the latter alone is practised when very fine adjustment of small currents is required, as, for example, in that form of surgical treatment known as electro-desiccation.

The spark-gap is shown separately in Fig. 36.

Diathermy Machine with Three-electrode Thermionic Valve.

A machine of this type is illustrated in Fig. 37. It is enclosed in a cabinet provided with swinging doors in front. When they are open, as shown in the figure, the current supplied to the machine is automatically interrupted. A plan of the constituent parts and their connections are shown in Fig. 38. The same numbers on this plan and in Fig. 37 correspond to the same parts. The three-electrode thermionic valve is shown at 9. The handle shown on the top of the cabinet (at H) is the coupling handle for regulating the current to the patient.

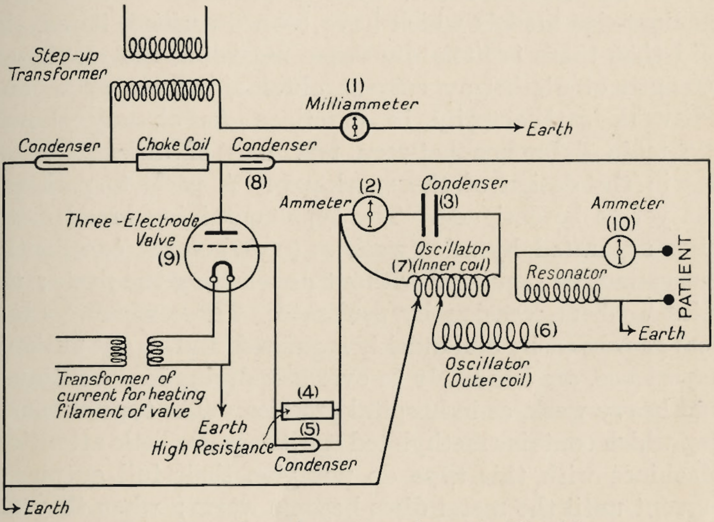

Fig. 38.—Plan of machine shown in Fig. 36.

This machine was constructed by the Nederlandsche Seintoestellen Fabriek, of Amsterdam.

Notes on the Various Models of Diathermy Machine.

With respect to the various models of diathermy machine, the selection will depend in the first place on the branch of therapy in which the practitioner is mainly interested. If he desires to practise surgical diathermy alone, the small models are suitable and will furnish the current required.

They are portable by motor-car. Small rotary converters, also portable by car, are made for use with these models for operations in private houses in which the main supply is D.C.

The smallest models are suitable for minor surgical work only, such as the cauterisation of vesical papillomata and small masses of abnormal tissue.

For medical diathermy the models of medium size will suit the major number of practitioners. They supply ample current for surgical work as well. With regard to the various medium-size models which have been described, it may be said that there is little difference regarding the maximum strength of diathermy current obtainable from each, and all work satisfactorily in practice. As already shown, the main difference between machines of different make lies in the design of the spark-gap. A perfect spark-gap has yet to be designed. The type containing broad metal discs separated by mica washers (p. 37) works excellently, but cannot be regulated without dissembling the parts; the mica washers occasionally perforate. Those which contain coal gas are easily and quickly regulated, and, in the author's experience, are less likely to overheat during long-continued and heavy work, as in hospital practice. The type of spark-gap which contains methylated spirit requires little attention. Machines with this type do not give their full output of current until the metal discs become warm; when they are started and the discs are cold a minute or two must elapse before they become warm enough to enable the machines to yield their full output.

If coal gas is not available a machine can be selected in which the sparks pass through air or methylated spirit.

Some machines deliver current at a higher maximum voltage than others. If the current has to traverse a lengthy course in the body, such as from foot to foot, or from hand to hand, it will produce more heat if it is at a high voltage. On the other hand, if the current passes through a broad region presenting a low resistance such as the chest or abdomen, it will produce more heat if it is at a relatively low voltage. Machines which deliver current at a high maximum voltage are most suitable for use with a condenser couch.

The author prefers the multiple spark-gap of the " open " type in which the sparks pass through the atmosphere between tungsten discs.[1] If there is a sufficient number of divisions there will be no overheating. Tungsten corrodes much more slowly than copper or silver. In " closed " gaps which contain coal-gas there is an accumulation of soot and the need for frequent cleaning. In medical diathermy it is very advantageous if the voltage at which the current is delivered can be varied within wide limits. The reason for this has been stated above. The writer is of the opinion that the maximum voltage at which the current is supplied in most machines might with advantage be further increased. He is at present investigating the subject and it appears that there is less unevenness in the degree to which different tissues on the path of the current are heated when the latter is delivered at higher voltage.

It is possible, however, to apply all the forms of diathermy treatment which are described in the present volume with all the machines of medium size that have been described, although, as stated above, some are more suitable for condenser couch work than others.

Machines of large size have not yet come into general use. Some have been adopted for hospital work and the treatment of more than one patient at the same time.

At the present time only one machine has been constructed for use without a rotary converter when the main supply is *direct* current. This has been described on p. 49. It can be used for surgical and medical diathermy. It is unsuitable for work with the condenser couch. Its output is smaller than that of machines of medium size operated by the main *alternating* current. On the other hand, it takes a smaller current and can readily be conveyed by private motor-car to the patient's home.

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[1] Spark-gaps of the multiple type between tungsten discs seem to be gaining popularity in Europe. They are almost universally used in America. They require very little attention and it is likely that they will be much more generally used in the near future. In this country Schall and Son and the Medical Supply Association have recently constructed machines with this type of spark-gap. The writer has worked with a large diathermy machine fitted with a spark-gap of this kind (shown in Fig. 36) made by H. G. Fischer and has found it needed no attention during the time it has been in use. A minor disadvantage of the multiple type of spark-gap is the noise made during operation. This can be lessened by enclosing the part in a case.

Machines which contain a thermionic valve do not require the periodic attention that has to be devoted to the spark-gap. They work without emitting a sound. In these machines there is much less waste of energy in the transformation of the low-frequency supply current into the high-frequency outgoing current. On the other hand, the life of the thermionic valve is limited. After the expiration of, say, 1,000 working hours a new valve must be fitted. Thermionic valves are costly. Smaller valves are less expensive than larger forms, but £10 is an average price.

The machine shown in Fig. 37 has been at work in the author's clinic about ten hours each week for nearly three years and is still in excellent order.

The Machine in Operation.

Machines fitted with spark-gaps produce a finely-crackling hissing sound. This sound comes from the spark-gap and is due to the discharges of the condenser. The sparks present the appearance of a non-luminous blue film when the metal bounding the gap is hot. When the metal is cold the film is luminous.

The operator should learn to recognise the sound made by his machine when the spark-gap is in order. If the sound is muffled the spark-gap requires attention, particularly if the muffling persists after the metal bounding the gap becomes hot. The attention that should be given to the spark-gap is described below.

When a patient is under treatment the movement of the amperemeter needle will indicate whether the spark-gap needs attention. A sudden swing-back of the needle towards zero or its failure to remain stationary shows that the spark-gap requires cleaning. When the machine has been in operation for a long time, without rest, the metal bounding the gap is liable to overheat, especially if a large current has been used. If it becomes too hot the diathermy current will diminish and the amperemeter needle will gradually move back towards zero. The modern types of spark-gap are more efficient in regard to absence of overheating than the original models.

Machines which contain spirit in the gap emit a spluttering noise when the gap is cold and yield little current until the metal becomes hot.

If two wires are connected to the terminals from which the diathermy current is taken, and their free ends brought near each other, a train of thick white sparks will pass across the gap in very rapid succession. In some machines they will pass when the ends are brought to an eighth of an inch from each other. In others they will bridge a longer gap.

Care of the Diathermy Machine.

The care of the diathermy machine is the care of the spark-gap. If this part does not receive periodic attention the machine will not give its full output.

The silver-faced copper discs of the spark-gaps in the machines by Dean, Siemens and Halske, etc. should be inspected every two or three weeks—if the machines are used daily. The silver surfaces tend to pit and become irregular after prolonged usage. When this happens they should be smoothed with emery paper. It is a good plan to place each pair of discs face to face, with a sheet of the finest emery paper in between, and rub each plate over the other. In this way a perfectly plane surface can be obtained. When the silver faces have been smoothed in this way the sparks crossing the gap acquire a yellowish hue and the machine does not give its maximum current for a few minutes. The non-luminous blue film gradually reappears and the current regains its full intensity. The silver loses its polish very quickly and assumes a dull grey colour; this is its normal appearance.

A thin grey deposit collects on the mica washers and should be wiped off occasionally with methylated spirit.

Perforation of a mica washer is recognised by a sudden increase of the customary sound heard when the machine is working normally. A small arc appears at the site of the perforation and the amperemeter needle falls back towards zero. The current supplying the machine must be stopped and a new washer fitted.

Soot accumulates in the chambers in which the sparks pass through coal gas and, if it is not removed, will eventually fill them completely. It should be cleared away after the machine has been in operation for a total duration of twelve hours. If this is not done the current supplied by the machine will diminish and tend to vary from minute to minute. The copper discs are very slowly consumed, but can be replaced by new ones when necessary. Before this, however, the surfaces between which the sparks pass tend to become irregularly concave or convex. As soon as this irregularity is noticed the surfaces should be smoothed with a fine file. If the practitioner is unable to obtain a smooth symmetrical surface the discs should be handed to a mechanic.

In the machines in which methylated spirit is supplied to the spark-gap the silver discs require smoothing every two or three months.

Apart from the attention required by the spark-gap the machine should be kept free from dust. If the main condenser is immersed in oil the latter tends slowly to creep up the sides of its container, and form a film on the cover. The latter should be wiped from time to time to prevent undue accumulation of oil.

It is a good plan for the operator occasionally to test the output of his machine by passing the current through himself by way of cylindrical electrodes grasped in the hands. This should be done when the machine is new, and the reading of the amperemeter noted when the machine is adjusted to give its maximum output. When the wrists are of average size the needle should indicate a current of 0·5 to 0·8 ampere according to the machine used. These figures refer to machines of medium size. If the amperemeter indicates less than the current yielded when the machine is in perfect order the spark-gap should receive attention.